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MIDDLE PROTEROZOIC PALEONTOLOGY OF THE BELT SUPERGROUP, GLACIER NATIONAL PARK

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Abstract—Glacier National Park in northwestern Montana holds significant geological and paleontological resources. The Middle Proterozoic sedimentary rocks exposed by the Lewis Overthrust span over 2,100 m of stratigraphic thickness, representing 800 million years of deposition. The glacial carving of the mountains and valleys that began 1.6 Ma left outcrops that are strangely unaltered. While the geological resources of the park have been substantially researched, the paleontological studies have been more sporadic. Precambrian formations of the Belt Supergroup hold a record of abundant ancient life, such as stromatolites and eucaryotes. Stromatolites within the parks were first recognized by Walcott in 1906. They have subsequently been studied in detail by Fenton and Fenton in the 1930s, Rezak and Ross in the 1950s and to a great extent by Horodyski from the mid-1970s to the 1990s. Current research conducted on the eukaryote *Horodyskia moniliformis*, from the Precambrian Appekunny Formation, and on the cone- and branching-shaped stromatolites of the Precambrian Siyeh Formation. These works yielded a great deal of knowledge about the paleontological history of the park but many more questions exist. Future explorations lie in the morphometric attributes, macrostructures and environmental conditions of the local stromatolites. Detailed study of the separate units within the park could also prove useful in the further search for fossils.

INTRODUCTION

The fossil resources of northwestern Montana's Glacier National Park (GLAC) are both renowned and yet obscure in the world of paleontology research (Fig. 1). When compared to other aspects of research within the park, it is apparent that fossils overall receive very little attention. However, the attention select fossils have received is considerable and thorough. The bulk of the research that has taken place has focused on the Precambrian algal mats, recording some of the earliest life on earth.

Known as the Belt Supergroup, the Middle Proterozoic rocks exposed in the park are 1.45 to 1.1 Ga (Fig. 2; Table 1). They were deposited in what is commonly referred to as the Belt Sea, a shallow, possibly inland sea, which covered much of the area during this time. The geological record for the Paleozoic and most of the Mesozoic is unknown in GLAC, with a small amount of Late Cretaceous (Campanian) and late Eocene to early Oligocene aged sediments being preserved within the park. On the eastern border of the park, Precambrian aged units overlie those of the Campanian due to faulting during the Tertiary. This is known as the Lewis Thrust Fault.

PALEONTOLOGISTS IN THE PARK: AN HISTORICAL BACKGROUND

Since before GLAC's establishment in 1910 as the tenth national park in the United States, there have been seven paleontologists who devoted research time to the paleontology of the park. The first major paleontological research was conducted during the summer of 1908 by Charles Doolittle Walcott (1906, 1908), who had been appointed the new Secretary of the Smithsonian Institution in 1907 (Yochelson, 2001). His panoramic photographs of the region from these excursions assisted George Bird Grinnell, who was a major player in the establishment of the park, to persuade congress to preserve the area. Walcott returned to the area in 1914, after his discovery of Cambrian fossils in the Burgess Shale of British Columbia, with his findings being published later that year (Walcott, 1914).

Two paleontologists, Carroll and Mildred Fenton, continued the work during the 1930s, publishing four papers on the area from 1931 to 1939 (Fenton and Fenton 1931, 1933, 1937; Fenton, 1939). In the 1950s, Richard Rezak (1953, 1954, 1957) conducted his dissertation research within the park and worked with Clyde P. Ross on a publication of the geology and paleontology of the park for the U.S. Geological Survey (Ross and Rezak, 1959). Rezak also wrote the first summary of stromatolites known from the Belt Series of GLAC.

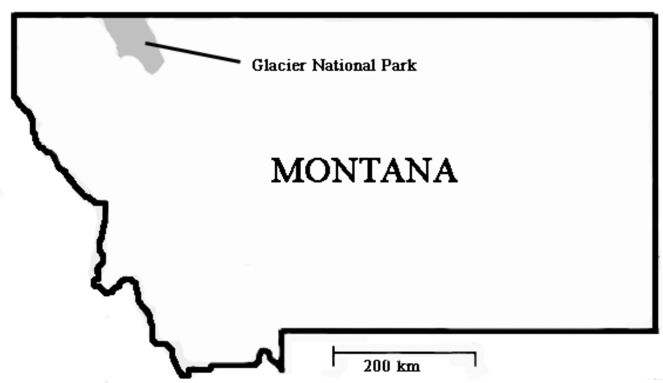

FIGURE 1. Location of Glacier National Park, Montana. Scale = 200 km.

The 1970s-1980s seem to be the peak of paleontological research within Glacier. During the 1970s to early 1980s, Brian White worked extensively on the columnar stromatolites found in the upper Altyn Formation. White published six reports (White, 1970, 1974a,b, 1979, 1984; White and Pedone, 1975) about these stromatolites, along with reports of microfossils from the Altyn Formation.

The 1970s also brought with it the man who would complete the bulk of the research done on the parks paleontological resources, to date. Robert J. Horodyski completed his dissertation on the stromatolites and paleoecology of the park in 1973 (Horodyski, 1973). From 1975 to 1994, he went on to publish and co-author over 15 reports on many aspects of the paleontology of the park from. In the mid-1990s, Horodyski began to work on pseudofossils from the Appekunny Formation with Mikhail A. Fedonkin of the Russian Academy of Science and Ellis L. Yochelson of the U.S. Geological Survey and Smithsonian Institution. Horodyski's untimely death in 1995 brought an abrupt end to his extensive research within the park. After Horodyski's death, Fedonkin and

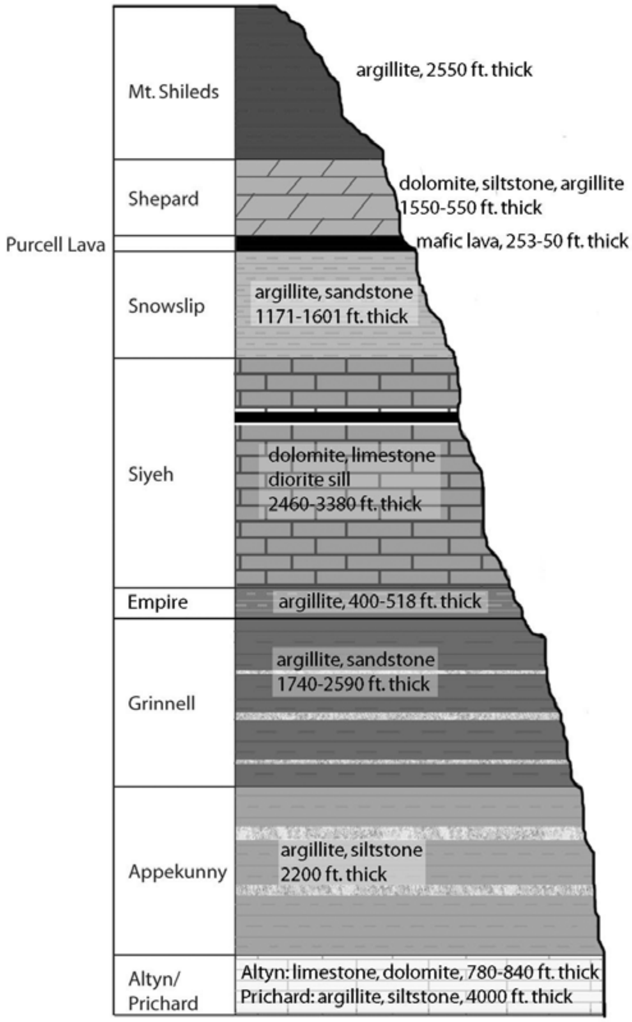

FIGURE 2. Stratigraphic column displaying the Precambrian Belt formations present in Glacier National Park, along with rock compositions and thickness.

TABLE 1. Precambrian fossils and formations listed in chronological order (rather than stratigraphic placement) within Glacier National Park, Montana.

Geologic Period	**Type of Formation/Location**	**Reported Fossils in Glacier**
Precambrian, Mid-Proterozoic	**Altyn/Waterton Formations:** dolomite, limestone, and arenite; Located in eastern portions of the park, Appekunny Falls.	Stromatolites, microfossils
	Prichard Formation: argillite, sandstone, limestone, breccia and arenite; Located in western portions of the park.	Microfossils
	Appekunny Formation: argillite, siltstone, arenite; Abundant outcrops throughout the park, Altyn, Apikuni, Running Wolf and Otokomi Mountains.	Microfossils, Eucaryotes
	Grinnell Formation: argillite and sandstone; well exposed throughout the park, Mt. Henkel.	Stromatolites
	Empire Formation: argillite, siltstone and sandstone.	None
	Siyeh (Helena) Formation: dolomite, limestone, arenite; Going-to-the-Sun Road, Grinnell Glacier and Logan Pass.	Stromatolites, microfossils
	Snowslip Formation: argillite, sandstone, siltstone, and breccia; exposed at higher elevations, Swiftcurrent Glacier, Piegan Mountain and Highway 2 near the Walton Ranger Station.	Stromatolites, microfossils
	Purcell Lava: mafic lava flows, altered basalt.	None
	Shepard Formation: dolomite, siltstone, argillite, sandstone, and limestone; Boulder Pass, Akamina Pass, Grinnell Glacier, Reynolds Mountain.	Stromatolites

Yochelson continued to work in the Appekunny Formation within the park. They have since published their findings on *Horodyskia moniliformis* (Yochelson and Fedonkin, 2000; Fedonkin and Yochelson, 2002), possibly one of the oldest known eucaryotes.

THE PRICHARD AND ALTYN FORMATIONS

The Prichard Formation, 1.375 to 1.4 Ga sandstone and siltstones, is only found on the western side of the park and is believed to be the age equivalent of the Altyn Formation, found in the eastern portion of GLAC. This formation has been reported to contain microfossils and pseudomicrofossils (Horodyski, 1981). The microfossils found in the dark gray mudstones of the Prichard Formation are of interest due to the fact that they demonstrate the effects of burial metamorphism on organic-walled microfossils. The fossils, which consist of black carbonaceous films, are very rare and poorly preserved, with only 12 known thus far. Due to the extent of their altered state, these fossils cannot be identified to the genus level and are therefore not useful for biostratigraphic correlations. The pseudomicrofossils from the formation occur as spheroids and filaments and illustrate an occurrence of non-biogenic carbonaceous microstructures that could be mistaken as authentic fossils (Horodyski 1981, 1993a).

The Altyn Formation, found in the eastern portion of Glacier National Park, is composed predominantly of 1.350 to 1.450 Ga limestones and dolomite. When the park was studied by paleontologists such as Charles Walcott around 1914, this formation was often referred to as the "Newland Limestone," a formation known from the Big Belt and Little Belt Mountains. The Fentons noted a stratigraphic error made by Walcott in assigning *Weedia tuberose* to the Altyn Formation. They reassigned this genus to the Siyeh Formation and also identified *Beltina* cf. *danaii* in the park (Fenton and Fenton, 1931, 1937; Horodyski, 1985a, 1993b). However, this remains an important discovery in that it is one of the earliest published reports of fossils from the park.

One of the significant contributions to the park's paleontology in the 1930s was the description of a massive bed of stromatolites located near Apikuni Falls (also known as Appekunny Falls) in the upper Altyn Limestone (Fenton and Fenton, 1931). These columnar stromatolites are located in a light gray to tan limestone that is some 6 m thick at the foot of Apikuni Mountain. They were named *Collenia columnaris* by Fenton and Fenton, with two other locations containing *C. columnaris* identified from within the park (Fig. 3; Fenton and Fenton, 1931, 1937; Horodyski, 1977). Another stromatolite group occurring above the *C. columnaris* zone was assigned to *Baicalia* by White (1970). Ross (1959) notes that the zones are well developed on both Apikuni ("Appekunny") and Divide Mountains, but poorly developed or absent in other areas,

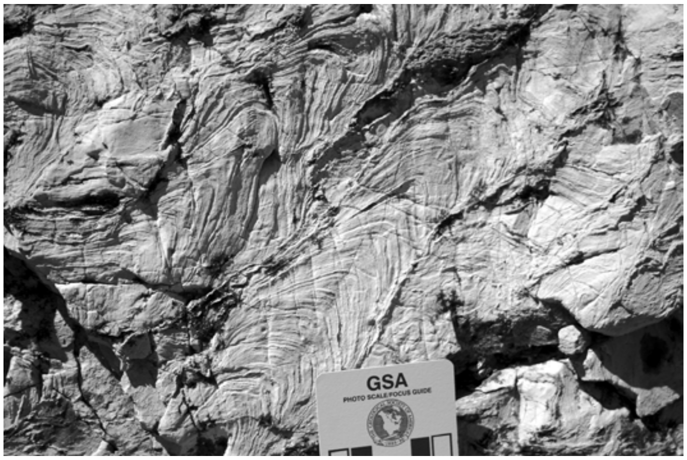

FIGURE 3. Altyn Formation columnar stromatolites "*Collenia columnaris*" found near Apikuni Falls, Many Glacier, Glacier National Park, Montana.

making it a discontinuous zone in the Altyn Formation. Horodyski (1976a) studied these stromatolites in great detail, describing three macrostructural varieties that occur in this horizon. In 1957, Rezak reassigned *Collenia columnaris* to *Collenia frequens* without explanation, assigning it as a "zone" due to its presence in two new locations (Ross and Rezak, 1959). Horodyski (1985a) took this a step further and referred to these stromatolites as "highly elongated, inclined stromatolites," rather than referring to them by a genus name. However, Horodyski still referred to the group *Baicalia* interchangabally with "branching stromatolite" (Horodyski, 1985a).

Baicalia is a branching columnar stromatolite forming in subtidal areas, where *C. columnaris* is a highly elongated, unbranched, columnar stromatolite living in quiet waters below the tidal zone. These stromatolites are tightly packed next to one another and would have formed reef-like masses similar to those seen in the vicinity of the contemporary Bahamas.

During their time in the park Fenton and Fenton (1931, 1937) also identified three new species from the Altyn Formation: *Newlandia sarcinula*, *Collenia albertensis* and *Morania antique*, although Rezak (1957) reassigns *Collenia albertensis* to *Collenia frequens*. White (1974a,b, 1979) also reports on an assemblage of microfossils that are comparable to modern blue-green algae and unicellular green algae from black chert found within the Altyn Formation (Horodyski, 1993b). Unidentified circular trace fossils found in the 1960s from the Altyn Formation are also still awaiting study (Fig. 4).

THE APPEKUNNY AND GRINNELL FORMATIONS

The Appekunny Formation is a 1.375 to 1.4 Ga mudstone, and is often referred to as the Appekunny argillite. This formation is the approximate temporal counterpart of the Grayson Shale in the Big Belt Mountains (Fedonkin and Yochelson, 2002) and can appear green in color, due to the large amount of chlorite minerals. Stromatolites were reported from the upper Appekunny Formation (Earhart et al., 1989), although no other reports have been made of stromatolites from the Appekunny argillite (Horodyski, 1985b). Authentic microfossils and pseudomicrofossils are also known from this formation, first reported by Horodyski (1981, 1993b) from dark gray to black fine-grained muddy sandstone, sandy mudstone and mudstones. The pseudomicrofossils appear to be organic envelopes and spiral impressions, while the authentic microfossils appear to be poorly preserved sphaeromorphs (Horodyski, 1993b). These sphaeromorphs are too poorly developed for general assignment, but are within the size range of prokaryotes (Fedonkin and Yochelson, 2002). Fedonkin et al. (1994) describe several types of sphaeromorphs, dubiofossils and pseudofossils from the Appekunny Formation. They conclude that some pseudofossils found

FIGURE 4. Trace fossil from Altyn Formation (GLAC 5749; photograph by Casey Wollschlaeger). Scale = 7 cm.

in this formation could be the result of sedimentary processes that are unknown today. However, they note that several of the surfaces were once "alive" and merit further study.

In 1972, Horodyski discovered a fossil he referred to as "problematic bedding-plane markings, each resembling a string of flat beads" near Apikuni Mountain (formerly Appekunny Mountain; Fig. 5; Horodyski, 1982a, 1983a, 1985a, 1993a,b). The validity and taxonomy of these markings were questioned for years by Horodyski and others. Often referred to as dubiofossils, in 1991 they were interpreted for the first time, as fossils of a megascopic organism. Yochelson et al. (1993) interpreted the remains to be "metaphyte or metazoan body fossils and/or trace fossils, although evidence of their organic origin is still not conclusive." After the death of Horodyski, Fedonkin and Yochelson (2002) continued to work on the "string-of-bead" fossils. Together they concluded that the remains belonged to a new type of eucaryote, which they named *Horodyskia moniliformis* (Fedonkin and Yochelson, 2002), in honor of the contributions of Horodyski to Precambrian paleontology. Similar fossils have also been recognized from rocks of comparable age in western Australia. Growth stages have been recognized for *Horodyskia* and its presence in an argillite signifies that it would have possessed a highly specialized mode of life. These fossil organisms are considerably older than other accepted multicellular organisms, making this a significant discovery.

The Precambrian Grinnell Formation is composed of an argillite, similar to the Appekunny Formation. The Grinnell argillite is rich in hematite, with occasional green banding due to the presence of chlorite. Fossils from this formation are rare, with only three areas documented

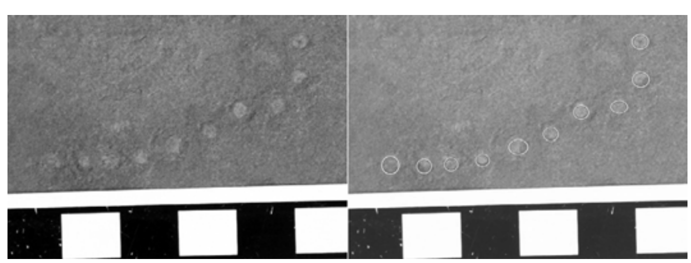

FIGURE 5. *Horodyskia moniliformis*, with "beads" traced to right (scale= 6 cm; photographs by Casey Wollschlaeger).

thus far. One occurrence of mound-shaped stromatolites was discovered in the summer of 1953 along Going-to-the-Sun Road in the St. Mary Valley (Fig. 6). These stromatolites were identified as *Collenia symmetrica*, *Cryptozoon occidentale* and *Collenia undosa* (Rezak, 1957). Mound-shaped stromatolites are also found in two locations on Mt. Henkel (Horodyski, 1983a, 1989). The scarcity of these fossils is most likely due to the high rate of deposition of terrigenous sediment that would have clouded the waters where these fossils attempted to survive. The algal components of stromatolites require clear waters in order to utilize photosynthesis. A high content of silt in the water would likely have halted this process.

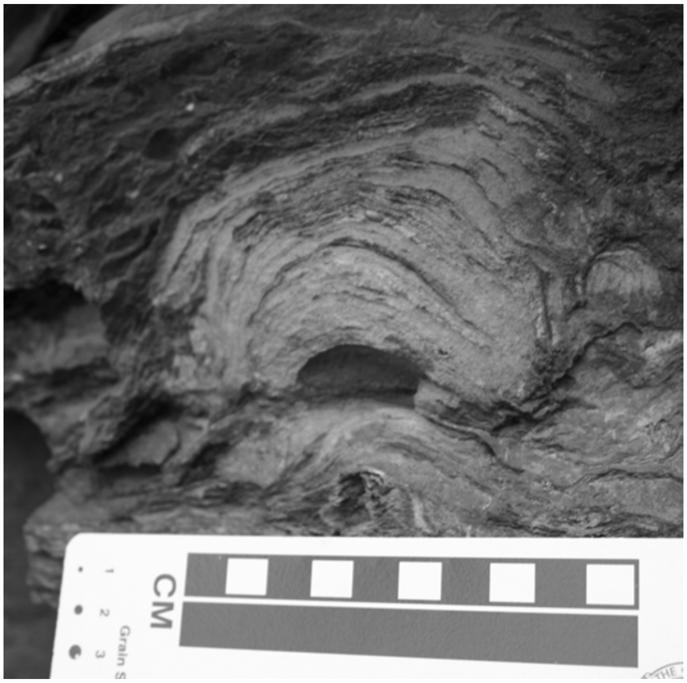

FIGURE 6. Small, mound-shaped stromatolite from the Grinnell Formation along Going-to-the-Sun Road.

THE HELENA (SIYEH) FORMATION

The Helena Formation (also known as the Siyeh Formation) is by far the best exposed formation in the park. This formation outcrops as one drives along the Going-to-the-Sun Road alongside the Garden Wall, up to the western flank of Going-to-the-Sun Mountain in the Saint Mary Valley and in several other locations within the park, particularly in Two Medicine and the Many Glacier areas. This 1.1 Ga limestone formation also contains numerous fossils. Seven species of stromatolites have been described from the formation, along with filamentous microfossils and puzzling "molar-tooth structures."

Mound-, conical- and dome-shaped stromatolites are so abundant in the Helena (Siyeh) Formation that they are now often grouped in zones. These zones are typically somewhat continuous and have a general similar thickness. The Fentons worked extensively in the Helena (Siyeh) and first described four subdivisions and stromatolite zones within the park. Some of these zones are so persistent that they are often called bioherms (Fenton and Fenton, 1933). Some of these well exposed zones can be seen at the foot of Grinnell Glacier, along the trail leading to Granite Park chalet, and near Hole-in-the-Wall. Rezak (1957), and later with Ross (Ross and Rezak, 1959), redefine these into three zones. Afterward Horodyski (1985b, 1989) redefined the zones into cycles, specifically the *Jacutophyton* and *Baicalia-Conophyton* cycles. The *Baicalia-Conophyton* cycle is subdivided into six distinct units by Horodyski and composes 70% of the actual volume of stromatolites from within the Helena (Siyeh) Formation (Fig. 7). Horodyski conducted thorough research on the Siyeh stromatolites, resulting in eight publications. Isolated stromatolite occurrences not associated with these cycles are also known from within the park.

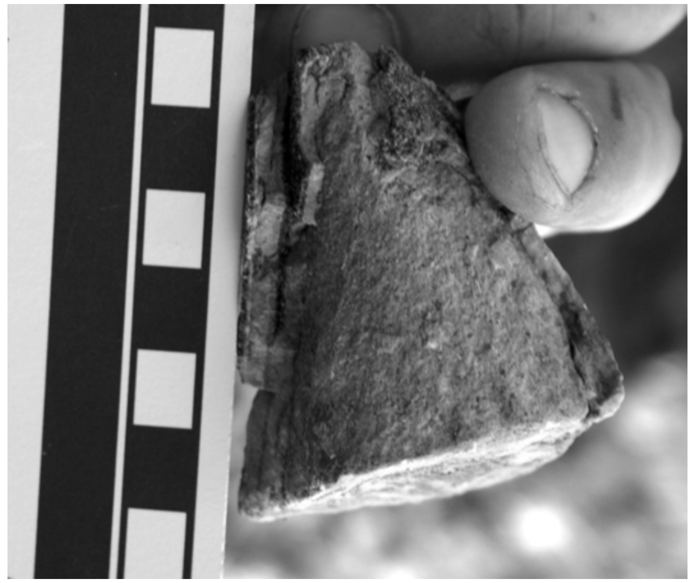

FIGURE 7. The conical stromatolite, Co*nophyton,* from the Siyeh Formation, Glacier National Park. Scale=7 cm.

Sedimentary structures, such as mud cracks, scour marks and load-casts are common in the Helena (Siyeh) Formation. Fenton and Fenton (1937) describe pelecypod burrows and trails near Dawson Pass. It is commonly believed that the remains described by Fenton and Fenton (1937) can be attributed to these non-organic remains. Microfossils have also been described from chert in the lower portions of the *Baicalia-Conophyton* cycles (Horodyski, 1985a).

The Helena (Siyeh) Formation also contains one of the strangest pseudofossils to be described from the park – the molar-tooth structure (Fig. 8). These irregular patterns were first described by Bauerman (1885) and are thought to resemble the grinding surface on the molar teeth of elephants. They have been considered to be organic in origin by several authors; an idea often contested. Daly hypothesized that these structures were the result of "secondary tectonic segregation" (Daly, 1912; O'Connor, 1972). Walcott (1914) described these structures as organic

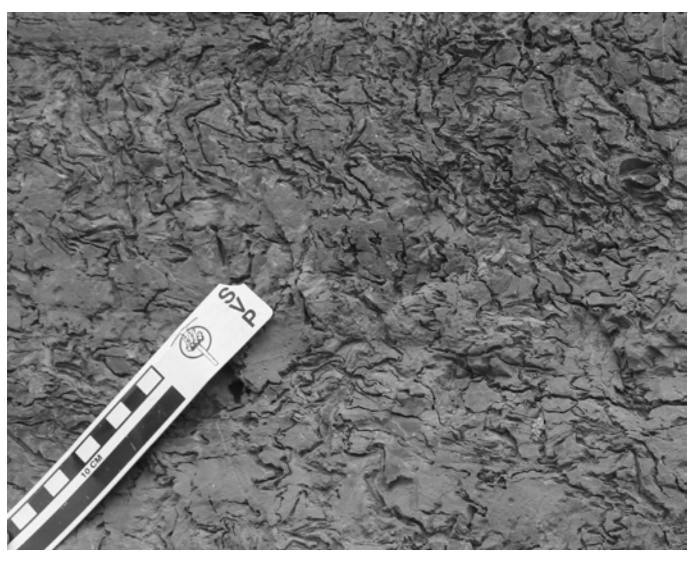

FIGURE 8. Molar tooth Structure, Siyeh Formation, Going-to-the-Sun Road, Glacier National Park. Scale = 10 cm.

remains, believing them to be algal, and named three types, *Greysonia*, *Copperia* and *Weedia*. Fenton and Fenton (1937) and Rezak (1957) concur with Daly's hypothesis, where O'Connor (1972) and Smith (1968) interpret them as having a syndepositional origin, as a direct result of algal activity (Horodyski, 1993b). However, Ross (1959) also attributed the structures to an organic source. Horodyski (1976b, 1983b, 1985a,b, 1989) interprets them as being produced as a result of calcite infill of open-space structures. Overall, the prevailing opinion regards these molar-tooth structures as inorganic remains.

THE SNOWSLIP AND SHEPARD FORMATION

In publications from the 1930s to 1976, the Snowslip and Shepard Formations are often grouped together and referred to as the Missoula Group. In 1977, the current formation names were proposed. The Snowslip Formation is exposed locally at high elevations within the park and forms the base of the Missoula Group. This one billion year old formation contains calcitic or dolomitic red and green argillites, siltstones and sandstones and represents a subtidal to intertidal setting with occasional subaerial exposure. Pseudocolumnar and mound-shaped stromatolites, or stromatoloids, are known from five locations, with filamentous and pillar-shaped microfossils detected from a stromatolite (or stromatoloid) in the lower part of the Snowslip Formation (Horodyski, 1977, 1983a, 1985a, 1993a,b). Rezak (1957) describes the stromatolites *Collenia undosa, Collenia symmetrica* and *Cryptozoon occidentale* from locations along Highway 2 on the southern border of the park (Fig. 9).

The Shepard Formation is highly eroded, existing only in higher elevations within the park. It is predominantly composed of dolomite, siltstones, argillite and quartzite and overlies the 1.5 to 1.845 Ga Purcell Lava (Aleinikoff et al., 1996). Fenton and Fenton (1931) report several species of stromatolites from the Shepard Formation: *Collenia parva*, *Collenia clappii* and *Collenia undosa*. They also describe "problematic structures" from the base of the Shepard, later known as "molar-tooth structures," also noted by Horodyski (Fenton and Fenton, 1931; Horodyski, 1985a). Mound-shaped stromatolites were also located in this formation by Horodyski (1982a) on Reynolds Mountain.

FIGURE 9. "*Collenia undosa*" from the Snowslip Formation near the along Highway 2, Glacier National Park. Scale = 10 cm.

SUMMARY

The fossil remains of Glacier National Park comprise one of the richest accumulations of Precambrian life in the northwestern United States. While these fossils are often overlooked, the amount of knowledge that can still be gained from them is immense. Future explorations may include morphometric attributes, macrostructures and environmental conditions of the local stromatolites. Still lacking is a detailed correlation of the Belt Supergroup rocks present in the park with those found to the south, north and west. Microscopic study of the preserved sedimentary Belt rocks of GLAC, investigations of the erosion difference between *Conophyton* and *Baicalia* stromatolites and the origins of Altyn circular trace fossils are all possible research topics to be addressed within the park. Overall GLAC holds a wealth of Middle Proterozoic, well preserved fossil remains from which researchers, park staff and visitors alike can learn much. The opportunity to learn more about the Precambrian fauna and environmental conditions offers a glimpse into a wider ecological and biological window of an immense time span on the North American continent.

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